LASER BEAM INTERFERENCE OPTICAL INFORMATION RECORDING/REPRODUCING APPARATUS COMPRISING HOLOGRAPHIC RECORDING MATERIAL AND OPTICAL INFORMATION RECORDING/REPRODUCING METHOD

1. Field of the Invention

This invention relates in general to an optical recording and reproducing apparatus. Specifically, this invention relates to a novel optical recording and reproducing apparatus and a method that make it possible to increase storage capacity.

2. Background of the Invention

Initialized by an increase in information that needs to be processed by data communication systems and computer systems, a variety of optical data recording and readout systems have been designed and provided. The typical examples of the optical data recording and readout system are ones such as a compact disk player, CD-ROM, Magneto-Optical Disk, and DVD(Digital Versatile/Video Disk). However, the vast increase in data that needs to be processed by data communication and computer systems may require even higher capacity storage systems in the near future.

In order to maximize the stored data capacity, a method which employs an optical disk with multi-layered data recording layers has been applied to some conventional optical data recording and reproducing apparatus. However,

this method is required to overcome a disadvantage on signal to noise ratio (S/N ratio) caused by an interference light reflected from neighboring data layers. Therefore, the conventional method is forced to set a limit on data capacity dependent upon the interference light from neighboring data layers in the multi-layered optical disk system. Furthermore, another method for increasing a pit density on each data layer surface is also applied to some conventional optical data recording and reproducing apparatus, but the S/N ratio becomes even worse by the interference light from the neighboring layers.

Recently, holographic memories or various types of information recording and reproducing systems employing holographic material have been under development and some of them have already been realized. These holographic recording and reproducing systems have been employing an information recording method that a signal light based on recording data and a reference light are interfered each other within a holographic material so as to generate an interference fringe, and the interference fringe is recorded in the holographic material. And in order to readout the recorded interference fringe, only the reference light is energized onto the recorded interference fringe, thereby the reference light diffracted by the interference fringe being detected as a read-out signal. A major advantage for the holographic recording and reproducing system employing the interference fringe diffraction method lies on capability to reduce an

effect by the reflection light from the neighboring data layers or the neighboring recorded fringes in each data layer. And this advantage makes it possible to increase a data recording density and a number of data layers.

Fig. 6 shows a structure of a conventional holographic information recording and readout apparatus. A laser beam 40 emitted from a light source (not shown) is modulated by a spatial light modulator 41 thereby transmitting a signal light. The spatial light modulator 41 can convert a preferred signal into a two-dimensional signal pattern that is called a page data, and generate the signal light by opening and closing modulation at a set of pixels in the spatial light modulator 41 in accordance with the page data. The signal light transmitted from the spatial light modulator 41 is modulated to a flat light beam by being passed through a cylindrical lens 42, and the signal light is projected onto a holographic medium 43. At the same time, an another light source emits a laser beam 44 as a reference beam so that the signal light and the reference light are interfered each other so as to generate an interference fringe which is recorded onto the holographic medium 43. Multiple recording is possible at the same area of the holographic medium 43 by modulating the projection angle of the signal light to interfere with the reference light. In order to read-out the recorded data, only the reference light needs to be projected onto the recorded area of the holographic medium 43 at the same angle as that of the

recording process. By projecting the reference light onto the recorded area of the holographic medium 43, the reference light is diffracted selectively by the interference fringes dependent upon the interference projection angle so that a reproduction light is generated. The reproduction light is collimated by a lens 45, and detected by a CCD (Charge Coupled Device) array 46. The detected signal by the CCD array 46 is decoded from the two-dimensional signal to the original information signal.

The holographic data recording and readout apparatus in Fig.6 must have two laser sources; one laser source being to emit the signal light beam and the other being to emit the reference light beam. And this is a characteristic aspect that those two laser beams interfere with each other and the interference fringes are recorded onto a holographic material. Since such a holographic information recording and readout system is very complicated in structure so that conventional components employed by the conventional optical recording and reproducing system can not be used. More importantly, the holographic information recording and readout system can not provide a compatibility function with conventional CD or DVD media. In addition, since the holographic information recording and readout apparatus is characterized by its recording method to produce and record the two-dimensional page data, the spatial light modulator 41 is an indispensable component. However, in order to control the spatial light modulator 41, complicated circuits are required, and the

recording speed is limited by the modulation speed of the spatial light modulator 41. Also, to readout the recorded information, the two-dimensional signal has to be detected by the CCD array 46, which requires complicated decoding circuits as well.

3. Summary of the Invention

An object of the present invention is to provide a novel optical recording and reproducing system, which employs only a single set of light sources to generate interference fringes for data recording. Another object of the present invention is to provide a holographic information recording and reproducing system which employs a novel method for maximizing a recording and reproducing speed, in which a spatial light modulator is no longer necessary. Still another object of the present invention is to provide a holographic information recording and reproducing system, which has a compatibility function with conventional CD or DVD media. Still another object of the present invention is to provide a holographic information recording and reproducing system, which employs a relatively simple apparatus that makes it possible to down-size its component. Also, the present invention can be achieved by the combination of conventional components, which will contribute to provide consumers with a low-priced system.

The object of the present invention is achieved by a laser beam interference optical information recording apparatus for recording on an optical information recording

medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer comprising: a light source for emitting a coherent laser beam, a light source modulation means for driving a pulse emission of the light source so as to produce a signal light in response to an original information signal to be recorded, and an optical system arranged to focus the signal light onto the information recording layer in a direction from the other surface of the information recording layer so as to at least partially reflect the signal light from the reflection layer, to focus a recording reference light onto the information recording layer in a direction from said one surface of the information recording layer so as to interfere the signal light with the recording reference light onto the information recording layer to generate an interference pattern, and to record the interference pattern onto the information recording layer.

The optical system of the present invention may comprise: a collimate lens for collimating the signal light from the light source, a beam-splitter for diffracting the signal light transmitted from the collimate lens, a focusing lens for focusing the signal light from the beam-splitter onto the information recording layer, and an actuator for driving the focusing lens. Also, the light source may be constituted of a laser diode.

The object of the present invention is further

achieved by a laser beam interference optical information reproducing apparatus for reading from an optical information recording medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer comprising: a light source for emitting a coherent laser beam, a light source modulation means for driving the light source so as to produce a reproducing reference light, an optical system arranged to focus the reproducing reference light onto the information recording layer in a direction from the other surface of the information recording layer so as to retrieve a reflection light diffracted by an interference pattern recorded onto the information recording layer, and a photo-detector for receiving the reflection light from the optical system so as to detect an electric signal in accordance with an information recorded onto the information recording layer.

At this time, the reproducing reference light should be adjusted to have strength enough to have little effect on the interference pattern recorded onto the information recording layer.

The optical system of the present invention may comprise: a collimate lens for collimating the reproducing reference light from the light source, a beam-splitter for diffracting the reference light transmitted from the collimate lens, a first lens for focusing the reproducing reference light from the beam-splitter onto the information

recording layer, an actuator for driving the first lens, and a second lens for guiding a reflection light diffracted from the information recording layer to the photo-detector passing through the first lens and the beam-splitter. Also, the light source may be constituted of a laser diode.

Moreover, the object of the present invention is achieved by a laser beam interference optical information recording/reproducing apparatus for recording/reproducing on an optical information recording medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer comprising: a light source for emitting a coherent laser beam, a light source modulation means for driving a pulse emission of the light source so as to produce a signal light in response to an original information signal at the time of recording, and for driving the light source so as to produce a reproducing reference light at the time of reproducing, an optical system arranged to focus the signal light onto the information recording layer in a direction from the other surface of the information recording layer so as to at least partially reflect the signal light from the reflection layer, to focus a recording reference light onto the information recording layer in a direction from said one surface of the information recording layer so as to interfere the signal light onto the information recording layer to generate an interference pattern, and to record the interference pattern onto the

information recording layer at the time of recording, and arranged to focus the reproducing reference light onto the information recording layer in a direction from the other surface of the information recording layer so as to retrieve a reflection light diffracted by an interference pattern recorded onto the information recording layer at the time of reproducing, and a photo-detector for receiving the reflection light from the optical system so as to detect an electric signal in accordance with an information recorded onto the information recording layer.

The optical system of the present invention may comprise: a collimate lens for collimating the signal light or the reproducing reference light from the light source, a beam-splitter for diffracting the signal light or the reproducing reference light transmitted from the collimate lens, a first lens for focusing the signal light or the reproducing reference light from the beam-splitter onto the information recording layer, an actuator for driving the first lens, and a second lens for guiding a reflection light diffracted from the information recording layer to the photo-detector passing through the first lens and the beam-splitter.

At this time, the reproducing reference light should be adjusted to have strength enough to have little effect on the interference pattern recorded onto the information recording layer. Also, the light source may be constituted of a laser diode.

According to the other aspect of the present

invention, there is also provided a laser beam interference optical information recording method for recording on an optical information recording medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer, comprising steps of: driving a pulse emission of a light source for emitting a coherent laser beam so as to produce a signal light in response to an original information signal to be recorded, focusing the signal light onto the information recording layer in a direction from the other surface of the information recording layer so as to at least partially reflect the signal light from the reflection layer, focusing a recording reference light onto the information recording layer from said one surface of the information recording layer so as to interfere the signal light with the recording reference light onto the information recording layer to generate an interference pattern, and recording the interference pattern onto the information recording layer.

According to another aspect of the present invention, there is provided a laser beam interference optical information reproducing method for reading from an optical information recording medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer, comprising steps of: driving a light source for emitting a coherent laser beam so as to

produce a reproducing reference light, focusing the reproducing reference light onto the information recording layer in a direction from the other surface of the information recording layer so as to retrieve a reflection light diffracted by an interference pattern recorded onto the information recording layer, and receiving the reflection light so as to detect an electric signal in accordance with an information recorded onto the information recording layer.

At this time, the reproducing reference light should be adjusted to have strength enough to have little effect on the interference pattern recorded onto the information recording layer.

According to the other aspect of the invention, there is provided a laser beam interference optical information recording/reproducing method for recording/reproducing on an optical information recording medium comprising an information recording layer made from holographic material and a reflection layer disposed relative to one surface of the information recording layer, comprising steps of: driving a pulse emission of a light source for emitting a coherent laser beam so as to produce a signal light in response to an original information signal to be recorded at the time of recording, driving the light source so as to produce a reproducing reference light at the time of reproducing, focusing the signal light onto the information recording layer in a direction from the other surface of the information recording layer so as to at least partially

reflect the signal light from the reflection layer, focusing a recording reference light onto the information recording layer in a direction from said one surface of the information recording layer so as to interfere the signal light onto the information recording layer to generate an interference pattern, and recording the interference pattern onto the information recording layer at the time of recording, focusing the reproducing reference light onto the information recording layer in a direction from the other surface of the information recording layer so as to retrieve a reflection light diffracted by an interference pattern recorded onto the information recording layer, and receiving the reflection light so as to detect an electric signal in accordance with an information recorded onto the information recording layer at the time of reproducing.

At this time, the reproducing reference light should be adjusted to have strength enough to have little effect on the interference pattern recorded onto the information recording layer.

4. Brief Description of the Drawings

Fig.1 shows a schematic diagram of the present invention;

Fig.2 shows a schematic diagram to explain a recording procedure of the present invention;

Fig.3 shows a schematic diagram to explain a reproducing procedure of the present invention;

Fig.4 shows a schematic diagram to explain a

function of the interference fringe of the present invention;

Fig.5 shows a block diagram of the optical recording and reproducing system of the present invention; and

Fig.6 shows a schematic diagram of a conventional holographic recording and reproducing system.

5. Detailed Description of the preferred Embodiment

Embodiments of the present invention will be explained with reference to the drawings.

Fig.1 shows a schematic diagram to explain fundamental principle of the present invention. A holographic disk 01 is employed as an optical information storage medium in this particular embodiment. The holographic disk 01 has a multi-layered structure having a transparent substrate 02, a hologram layer 03 containing holographic material such as Lithium Niobate ($LiNbO_3$), a reflection layer 04 to reflect an incident light, and a protective layer 05. A coherent laser beam emitted from a laser diode 06, is collimated by a lens 08, and the laser beam is diffracted by a beam-splitter 09. Then, a focusing lens 10 focuses the laser beam onto the hologram layer 03 in the holographic disk 01. An actuator 11 modulates the focusing lens 10 to scan the focal point crossing through each layer in the holographic disk 01, and the actuator 11 adjusts the focal point in accordance with the detected focus error signal. After the laser beam is focused onto the hologram layer 03 by the focusing lens 10, the laser beam is partially propagated into and passes through the hologram

layer 03 so as to be reflected by the reflection layer 04. Then, the reflected laser beam interferes with the focused laser beam so that the interference fringes are recorded onto the hologram layer 03. In order to reproduce the recorded interference fringes, the laser diode 06 is emitted at low intensity to prevent from affecting or erasing the recorded interference fringes. Then, the emitted laser beam is collimated by a lens 08 and the laser beam is diffracted by a beam-splitter 09. Then, the focusing lens 10 focuses the laser beam onto the hologram layer 03 in the holographic disk 01. If there exists the recorded interference fringe, a reflected laser beam by the interference fringe will be produced by the diffraction from the interference fringe. The reflected laser beam by the interference fringe is transmitted through the focusing lens 10 and the beam-splitter 09, then focused by a lens 12 so as to be detected by a photo-detector 13. By processing the detected signal, the existence of the interference fringe is indicated by the signal intensity variation. The original information data is reproduced by processing the detected signal.

Fig.2 shows a schematic diagram to explain a recording procedure of the exemplified application of the present invention. The holographic disk 01 has a multi-layered structure having a polycarbonate transparent substrate 02, a hologram layer 03 containing Lithium Niobate ($LiNbO_3$), a reflection layer 04 containing aluminum (Al) to reflect an incident light, and a protective layer 05. A

laser diode 06 that emits a coherent laser beam is controlled by a laser diode driver 07 to modulate pulse emission according to an original digital signal to be recorded. In this application, the laser diode 06 emits a coherent laser beam for the "1" digital code of the original signal, and the laser diode 06 does not emit for "0" digital code by the pulse modulation. Under a state of "1" digital code of the original signal, a coherent laser beam emitted from the laser diode 06 is collimated by a lens 08 and the laser beam is diffracted by a beam-splitter 09. Then, a focusing lens 10 focuses the laser beam onto the hologram layer 03 in the holographic disk 01. An actuator 11 modulates the focusing lens 10 to scan the focal point crossing through the each layer in the holographic disk 01 and the actuator 11 adjusts the focal point in accordance with the detected focus error signal. Also, by detecting the reflected laser beam while modulating the focusing lens 10 with the actuator 11, the position of the hologram layer 03 and the thickness of the holographic disk 01 are detected so that a type of the optical data medium can be recognized. The laser beam focused onto the hologram layer 03 by the focusing lens 10, partially propagates and passes through the hologram layer 03 and is reflected by the reflection layer 04. Then, the reflected laser beam interferes with the focused laser beam so that the interference fringe is recorded onto the hologram layer 03. The recorded status 03a indicates "1" digital code of the original data. For "0" digital code of the original

data, no interference fringes will be recorded because the laser diode 06 does not emit a laser beam at all. The unrecorded status 03b is the recorded status which records "0" digital code of the original data.

Fig.3 shows a schematic diagram to explain a reproducing procedure of the exemplified application of the present invention. In order to reproduce the recorded interference fringe, the laser diode 06 emits laser beam at low intensity to prevent from affecting or erasing the recorded interference fringe. Then, the emitted laser beam is collimated by a lens 08 and the laser beam is diffracted by a beam-splitter 09. Then, a focusing lens 10 focuses the laser beam onto the hologram layer 03 in the holographic disk 01. If there exists the recorded interference fringe (recorded status 03a), a reflected laser beam by the interference fringe will be produced by the diffraction from the interference fringe. If there exists no recorded interference fringe (unrecorded status 03b), a reflected laser beam by the interference fringe will not be produced, of course. The reflected laser beam by the interference fringe is transmitted through the focusing lens 10 and the beam-splitter 09, and then focused by a lens 12 and detected by a photo-detector 13. By processing the detected signal, the existence of the interference fringe is indicated as the signal intensity variation. The original information data is reproduced by processing the detected signal.

Fig.4 shows a schematic diagram to explain a

function of the interference fringe of the present invention. The laser beam projected by a laser diode (not shown) is focused by the focusing lens 10 onto the center of the hologram layer 03 in the holographic disk 01, by modulating the actuator 11. Then, the focused laser beam by the focusing lens 10 interferes with the reflected laser beam from the reflection layer 04 after passing through the hologram layer 03, thereby revealing the recorded status 03a. At the reproduction procedure, by focusing the laser beam onto the interference fringe (recorded status 03a) at low intensity to prevent from affecting or erasing the recorded interference fringe, the reflected laser beam by the interference fringe will be produced by the reflection from the interference fringe. If there exists no recorded interference fringe (unrecorded status 03b), the reflected laser beam by the interference fringe will not be produced, of course. While focusing the laser beam onto the interference fringe, some of the reflected laser beam from the reflection layer 04 would be produced. The reflected laser beam does have enough intensity to cause the interference with the focused laser beam because the hologram layer is located very closely. However, the reflected laser beam from the reflection layer 04 will not affect the detector as a noise because the reflected laser beam has been already focused so that the reflected laser beam will be propagated.

Fig.5 shows a block diagram of the exemplified

application of the optical recording and reproducing system of the present invention. For this particular application, the holographic disk 01 is fixed onto a spindle 20, the spindle 20 is rotated by a spindle motor 21. The spindle motor 21 is modulated by a spindle servo circuit 22 according to the data recording procedure or the data reproducing speed. A pick-up 23 is constituted of the similar optical components described in Fig. 1, 2 or 3. The pick-up 23 is driven by a pick-up servo 24 in a radius direction from the center to the rim of the holographic disk 01 by sliding the pick-up 23. By sliding the pick-up 23, the focal point of the laser beam can access any data area on the holographic disk 01. The reflected signal from the interference fringe is detected by a photo-detector in the pick-up 23, and then the detected signal is processed by a signal processor 25 to detect a focusing error signal. According to the focusing error signal, the focusing lens is modulated by an actuator operated by a focusing servo circuit 26 and a tracking servo circuit 27 in order to adjust the focal point or to recognize a type of the optical disk. A pick-up servo circuit 28 controls the pick-up servo 24 to slide the pick-up 23 in a radius direction from the center to the rim of the holographic disk 01. The spindle servo circuit 22, the focusing servo circuit 26, the tracking servo circuit 27, and the pick-up servo circuit 28 are integrally controlled by a servo controller 29 according to the operation signal from the signal processor 25. A data processor 31 decodes the

detected signal by the signal processor 25. All circuits are fully controlled by a system controller 30 as a central processing circuit.

6. Industrial applicability

As described above, the present invention enables to employ only a single set of the light source to generate a interference fringe for data recording. In addition, the present invention enables to maximize recording and reproducing speed without using a spatial light modulator which was indispensable for the conventional holographic data recording and reproducing system. Moreover, the present invention has compatibility function with conventional CD or DVD media and a novel holographic data recording and reproducing system which provides a large amount of optical data recording and reproducing system by the combination of components.